INDIAN NOTES

WINTER 1974 • X NO. 1

MUSEUM OF THE AMERICAN INDIAN

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POLYCHROME URN

This magnificent painted vessel is unusually large for the ceramic art from this region. The designs represent masked figures and zoomorphic motifs. Collected by George G. Heye. See page 2.

Tiahuanaco-Huari		ca. 750-1000
Nazca, Peru	16/9700	10 x 12½ inches

IN THIS ISSUE

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A POLYCHROME URN FROM PERU

Anna C. Roosevelt
Curatorial Assistant

When George Heye was in Paris in 1926, he purchased a large Peruvian polychrome ceramic urn. The vessel, 12 ½" high, is decorated with bold representational designs in colors outlined in black.[1] The style and iconography of the Heye urn can be identified as belonging to the Middle Horizon period of Peruvian prehistory, 750-1000 A.D., the period of the rise and fall of the first great Peruvian empire, the Huari Empire. Because of certain unusual physical, stylistic, and iconographic aspects of the vessel, its authenticity has been in doubt ever since its acquisition. Dr. Junius Bird of the American Museum of Natural History and Robert Sonin, a ceramic specialist, had noted that the surface finish of the pot lacked the soft burnish typical of the more elaborate Middle Horizon wares, and that the quality of line and color in certain parts of the painted decoration was uncharacteristically poor. In addition, certain of the design themes painted on the pot: the bow and arrow in the hand of the main figure and the smiling face on the headdress of one of the flanking bodiless heads, were unique in the iconography of Peruvian Middle Horizon ceramic art (*Menzel: personal communication*).

Despite these discrepancies, Dr. Frederick Dockstader, Director of the Museum of the American Indian, had always been inclined to believe that the piece was genuine, and, in order to settle the question of its authenticity, recently initiated a reconsideration of the piece. By using various solvents on the surface of the urn and examining it under magnification, Sonin discovered that the problematical aspects of its finish and painting were the result of its having been repaired, repainted, and heavily lacquered at some point early in this century. The surface and fired pigments that he found under the indurated lacquer were consonant with a Middle Horizon date. Dr. Victor Bortolot of the Radiation Research Department at the Mount Sinai School of Medicine kindly undertook to make a thermoluminescence test of the clay of the pot in order to determine approximately how much time had elapsed since the pot had been fired (*see* Bortolot's article in this issue). The test produced a date of A.D. 843+340,-210 years and confirmed without a doubt that the urn had indeed been made during the Middle Horizon Period.

[1]The Heye urn was illustrated in Keleman (1946) Vol. II, Plate 164a, and was recently featured at the Metropolitan Museum of Art as No. 112 of the *Masterworks from the Museum of the American Indian* exhibition.

The Heye Urn is large, about 10" x 12 ½", and has hollow knob lugs at the sides below the rim and a single vertical strap handle at the back below the rim. The vase has the shape of a truncated oval, with a slightly inflected rim. It is decorated all over with black-outlined polychrome painted designs on a red slip background. Colors of the fired paints include red, maroon, tan, grey, cream, white, black and red. The rim of the vessel is decorated with a broad chevron band bordered above and below by a white band enclosed in black lines. The chevrons occur in a color sequence: cream, maroon, red, tan, grey, repeated around the rim. The strap handle bears the *fleur-de-lis* motif, and the knobs have serrated bands encircling them and a seven-point star at their ends (Plates II, III, and IV).

The body of the vessel is decorated with representational designs of humans and animals. The main figure in the decorative composition is that of a standing, front-facing man with a face modeled in three dimensions (*see* plate I). His black hair is cut short with bangs, and two flattened round nubbins protrude through his hair on the top of his head. His eyes are oval and staring, with small black pupils. His mouth is contracted in a rictus which exposes straight white teeth separated by red lines. His skin has dark red face paint; a scrolled and serrated black beard-like buccal mask encircles his mouth and his eyes are decorated with a cream colored circle on the left and a grey circle on the right. The angles of his nose are pierced by cylindrical black plugs, and its tip is covered by the upper part of the black buccal mask.

Around the man's neck is a necklace yoke of rectangular white objects that may represent shell placques sewn together. He wears a maroon tapestry shirt decorated on the front with a square panel of grey containing two rows of profile feline heads which face the midline of the tunic. The felines have drooping ears with rounded upper portions and pointed lobes. Every other profile head is red in color, with circular nose and nostril. The alternating heads are cream colored and have noses without nostrils. All the felines have vertically divided black and white eyes and white pointed fangs in the middle of each jaw.

The man's tan colored arms extend sideways out of the sleeveless armholes of his shirt and hold weapons. In the left hand is an axe with black handle, held with the head pointing downwards. Half of the axe-head is white, and the other is grey, decorated with two maroon bands slashed with white. The artist has placed the man's hands upside down on his body, so that the thumb is on the lower side of the hand while the palm faces forward. The white nails are squared on the fingers and sharply pointed on the thumb. Although the artist has achieved the impression that the hand is curling around the axe handle from behind, in actuality,

Huari Tiahuanaco polychrome urn, Nazca, Peru *circa* 900 A.D., height 12½". MAI/HF 16/9700.

Side View.

Rear View.

Side View.

the closed hand is represented as simply placed in front of the axe handle. The right hand holds a bow and a striped arrow with black triangular point and feathers. The arrow, like the head of the axe, points downward. The man's legs are bare from about the knee down, and each of the ankles is encircled with a maroon band. The feet point outward to the sides, and the heels bear a shield-shaped motif with its point directed toward the toes. Each "shield" has a black dot in its center. The four toes end in a straight line of square white nails.

Above each of the shoulders of the central figure is a profile human head facing toward the central figure. Each head has tan skin, a rounded nose with grey nostril or plug, and an oval mouth bared to show square white teeth. The eyes are smaller versions of the eyes of the central figure and are decorated with painted designs. That of the left-hand profile head is surrounded by an S-shaped ornament which has white dashes in its interior and two barb-like elements extending from it toward the ear. The folds and external meatus of his ear are rendered with red lines, and the lobe is obscured with a red-centered white disc ornament. The hair is straight and black and hangs down a little below the earring. The head is covered with a grey cap helmet containing a fan-shaped feathered crown ornament and studded chin and forehead bands. On the cap is painted a tan smiling face with black eye rings joined by a U-shaped line for the nose. from the sides of this face two curved spikes protrude, and the top of the head is decorated with a shield-shaped ornament.

The profile head above the right shoulder of the central figure is similar to the left-hand head except in its facial ornament and helmet. This face has a diamond of grey color around the eye and two white-tipped curving pointed elements extending from the corner of the mouth onto the cheek. The head is covered with a mushroom-shaped cap with maroon headband decorated with grey diamonds, each with a red dot inside. The upper part of the cap is divided into a cream half and a red half and is surmounted by a short grey featherlike ornament.

The back of the urn contains a complex emblem at the center of which is a rectangular cream colored face with black and white divided eyes and fangs (Plate IV). On the top of its head is a grey square surmounted by a tripartite feather ornament of grey with red-dotted, white tips. At either side of this face is the profile of a white-spotted maroon feline snake whose tail ends in the tripartite "tail feather" motif. Each "snake" has a white stripe on its underbelly and a recurved ray ornament extending forward from its tail.

On either side of the urn between the figure on the front and the complex emblem on the back are a pair of facing mythical creatures with

tightly curled tails and huge fanged teeth (Plates II and III). The eyes are round and white with black pupils, neither almond-shaped like the eyes of human figures on the pot, nor divided like those of the other figures. Their heads are round, their backs are humped, and their hands and feet are human in shape, with dotted "shield" heel designs on the feet and opposable thumbs on the hands. The heads, backs, tails, and with one exception, bellies of these creatures are decorated with recurved ray motifs tipped in contrasting colors.

The character of the painted iconography of the Heye urn is both secular and religious. The main figure is human and lacks the fangs, divided eye, and other attributes of deities. His shirt bears mythological designs in the form of profile feline heads similar to those on actual examples o similar tapestry shirts found on the south and central coast in the graves of elite individuals. The fact that he holds a weapon in each hand suggests further a military rôle.

Certain aspects of the animals adorning the sides and back of the vessel seem to suggest monkey attributes. Not only are their heads round and earless, their backs humped, and their tails tightly curled, but their feet and hands are identical to the human feet and hands on the vessel and on other Middle Horizon vessels. Ordinarily, human features on animals in Middle Horizon iconography are taken to indicate mythical identity; however, anthropoid feet and hands with opposable thumbs would be natural on monkeys. The possibility that these are monkeys is interesting in the light of the tropical forest character of bows and arrows, which were not a common coastal or highland Andean weapon in Peru after the later Preceramic period, *ca.* 2500 B.C. Since there is little evidence that the Huari conquerers reached the tropical forests, the combination of jungle motifs with emblems of war is curious. A substantial exchange of food and raw materials between the coast, sierra, and selva had started as early as the Initial period, 1800-1000 B.C. (Lumbreras 1972), however, and administration of trade may have been an important function of the Huari government. This would explain the co-occurrence on the pot of an elite secular figure with a tropical forest weapon and tropical forest animals. Another possibility is that the bow and arrow motif is simply a theme inherited from Tiahuanaco iconography. Standing figures of men holding bows and arrows are not uncommon on "classic" polychrome pottery from the site of Tiahuanaco.

Dorothy Menzel of the University of California at Berkeley concluded from a review of the urn's stylistic features that it was probably made somewhere in the Nazca drainage during the first years of the second epoch of the Middle Horizon, *ca.* A.D. 750-800, the epoch during which

the Huari Empire reached its greatest extent (*Menzel personal communication*). There are only two known deposits of oversized ceremonial pottery dated stylistically to the Middle Horizon Epoch 2A. A large offering cache has been found at Ayapata not far from Ayacucho (Ravines 1968), and a storage cache was excavated at a site in the Ocona Valley on the South Coast (Menzel 1968:68). Although the Heye urn shares certain features and themes, such as the modeled non-mythological human face, the hump-backed animal, recurved rays, the *fleur-de-lis*, profile bodiless human heads, and the "tail feather" with vessels from the above deposits, it does not share with them the style in which the features and themes are represented. For example, a modified *fleur-de-lis* design on the collar of one of the vessels from the Ocona Valley has elongated and rounded outlines unlike those on the handle of the Heye urn, which are chunky and have squared ray tips (Plate IV). The tripartite recurved ray features depicted on vessels from Ayapata and Ocona are different from those on the Heye urn, in that the former have a triangular tip added to the end of the central ray (Plates II and III).

The only existing vessels which are close to the Heye urn in both style and iconography are museum pieces which lack specific provenience information (Menzel 1964:49). One example (Larco 1966: Plate 106) is nearly identical to the Heye urn. It differs only in small details such as the proportions of headdress ornaments, the shape of mouths and the central figure's buccal mask, and the sequence of colors in the chevron band at the rim. There is another similar example in Ica, and one in a museum in Germany (Anton 1962: figure 107).

Definition of the style of the Heye urn and its placement within the stylistic sequence must await detailed comparisons with the many examples of Middle Horizon ceramic art that have known proveniences. The thermoluminescence technique, however, has demonstrated without a doubt that the Heye urn is worthy of integration into the corpus of Middle Horizon pottery. It is a process that will prove valuable to museums for the vindication of aberrant but important pieces in their archaeological collections.

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IMPRESSIONS OF TWO MOLDS

Curt Muser
Research Associate

In the collection of the Museum of the American Indian, there are two distinct applications of molded design that lend themselves to an interesting analysis. The first example studied consists of two ceramic pectorals of buffware, measuring 7 inches in height (Fig. 1). The first (5/6584), has been in the Museum since 1916, and the second (24/3020), was donated in 1969. Although over fifty years separate these acquisitions, they are identical twins. Variations exist only in extreme detail, caused by careless extraction from the mold, the free-hand punching of their two holes for attachment, and the later fractures relating to them. This mold contains a triangular face, with modeled eyebrows arching to the nose ridge, a slightly opened mouth, and with the "reserved expressivity" so characteristic of the style of Teotihuacan.

Simple clay baked molds may well have been man's first step into mass production. Once invented, their use spread throughout the New World.

The early figurines of the Valley of Mexico were modeled by hand in great variety and quantity. At the height of Teotihuacán's influence in classic times (A.D. 400-550), however, the typical triangular heads were mold-produced, with bodies and decorative details added by hand. Before the fall of this "City of the Gods" some hundred years later, completely mold-pressed figurines were in full production and were traded south to the Pacific, north to the Gulf and east as far as El Salvador.

The earliest applied decorative motifs pressed to the outside of ceramic vessels originated in the Valley of Mexico. Such a molded design is prepared separately – in a mold which in turn was fashioned from the "master work" – and pressed onto the vessel while wet. The function of a mold is in its repetitious use for the production of single pieces, whether they be complete unto themselves or for application to a vessel. A two-piece baked clay mold can impress its pattern over the entire outside of a bowl, often in relatively deep relief. In classic Meso-America an applied or molded design was characteristic of a widely traded pottery known as "Thin Orange." Molds were also utilized to produce the elaborate decorative elements of Teotihuacán and Monte Albán censers. The use of molds persisted into Aztec times and to the present day.

At the two upper sides of the headdress is the head of a bird or serpent, collared plumes extending above them, adorned with a *chalchihuitl* (jade) emblem. If the serpent identification is valid, then the elements extending

Fig. 1. Left, Teotihuacán buffware pectoral (5/6584). Right: Later example made from same mold (24/3020).

downward from them might be bifurcated tongues, exaggerated as a part of the total design. The crowning pattern in the headdress recalls the Oaxacan Glyph C, but such an identification seems tenuous.

The most likely assignment of these pectorals is to Teotihuacán III or IV (*ca* A.D. 500-700), produced at that site or perhaps at Azcapotzalco where the culture persisted after the collapse of Teotihuacán. They demonstrate the simplest manifestation of the molded technique: straightforward reproduction of a single piece.

The other example presented here of ceramic mold design duplication is considerably more complex and challenging. The proveniences of the two vessels involved do not agree, their sizes and styles are at variance, and the use of the original mold is incomplete in both cases. The prior existence of a third and larger bowl is suggested.

Both of these pots (Fig. 2) are Gray Ware, with the following comparative data:

		Large Bowl (A)	Small Bowl (B)
Acquisition No.		24/784	23/9540
Acquired		1968	1967
Total Height		6"	3 1/8"
Circumference	— base	21 1/8"	12½"
	— rim	19½"	12½"
Diameter	— rim	6 1/8"	4 1/8"
Legs		3 (1½" high)	none
Recorded Provenience		Campeche	Oaxaca

Fig. 2. Left, Grayware bowl (B) 3 1/8 in. high (23/9540). Right, Grayware tripod bowl (A) 6 in. high (24/784).

Calibration of the constituent parts of the molded decoration on each bowl shows a complete match despite the fact that one bowl (A) is almost twice the size of the other (B). The elements are of the same dimensions not only as they are repeated on the same vessel, but are identical with those on the other one as well. Surely both decorative bands derived their detail from the same original mold, or at least a mold made from the same "master bowl."

A drawing (Fig. 3) facilitates analysis by depicting the longest continuous sequence on bowl A. It is repeated in its entirety only twice. Dividing this sequence into sections *a, b* and *c*, the band of bowl A repeats itself *abc - bc - abc*, while the smaller pot B's series reads *b - b - b*. The maker of the small bowl either insisted on having a triple design sequence, or perhaps *b* was the only fragment remaining of the original mold suitable for reproduction.

There seems to be great credibility for the theory of the existence of a third and larger vessel, the mold for which was probably damaged. Otherwise it is difficult to explain the incomplete rendering of the "story" involved on the decorative band and the crude breaks in design continuity. A possible explanation is the use of part of the original molded appliqué to those vessels of smaller diameter and height. Surely the master mold was for a larger area than even bowl A provided, judging by the forced fitting of the story design into the inadequate space at top and bottom, as well as the crude breaks in horizontal continuity already mentioned.

The employment of parts of a damaged mold to secure the last drop of a popular design is practical and understandable. In this case it may be substantiated by detailed inspection of the wristbands of the recumbent

figures on bowl A. Two of the wristbands are sharply defined, like a pair of rectangles. On the third figure, however, the outlines are worn and appear as two hemispheres. Inspection of all three men on bowl B shows them to be duplicates of the latter. This hints that there is repeated use of only one figure from bowl A.

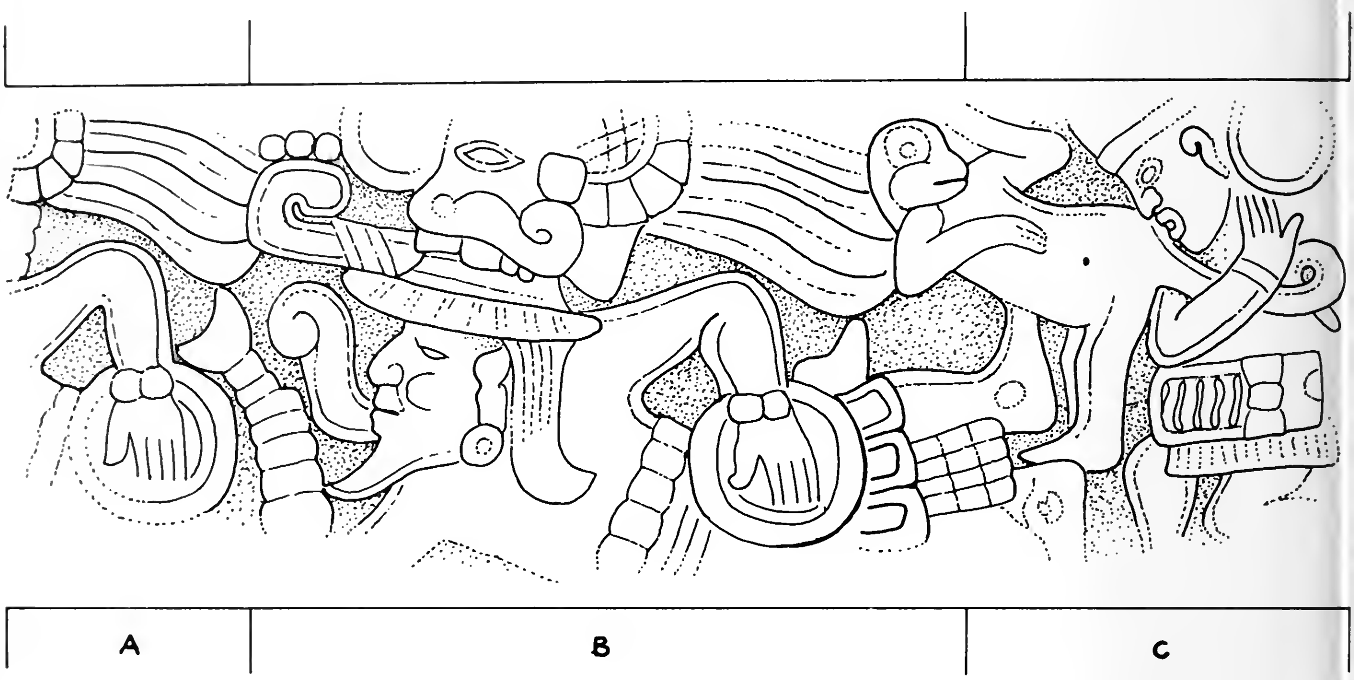

Fig. 3. Drawing of design sequence on Bowl A.

In these examples, we are dealing with two pieces of pottery neither of which is the handiwork of the original artist who created the design panel. The creator carefully conceived his work and sculpted it with great skill. Unfortunately, the subsequent employers of the mold seem to have been motivated to make and sell pots, unmindful of the artistry or quality of workmanship involved. They "mass-produced" by the mold for a market also no longer insistent on quality.

Important for a stylistic analysis of the two bowls is a discussion of their seemingly diverse proveniences. The smaller piece is said to have come from Oaxaca, probably because of the popularity of Gray Ware in that region over a long period of time.

The dominant figure on both vessels is a prone, bearded, forward-glancing man with his upraised left arm doubled back to his waist, and his feet slightly raised. In Oaxaca, such figures have been observed sculpted in stucco relief on Tomb I at Lambityeco (Fig. 4) along the Pan American Highway, and also in a tomb at Zaachila, a Zapotec capitol after the fall of Monte Albán. The Lambityeco relief resembles the molded figure in

conception but not in style or detail. Instead of a shield, the figure holds a human femur in his hand. The Zaachila example is even less pertinent. The bowls under study fail to evoke either the famous ceramic forms of Monte Albán or the later figures so well known to us through the colorful Mixtec codices.

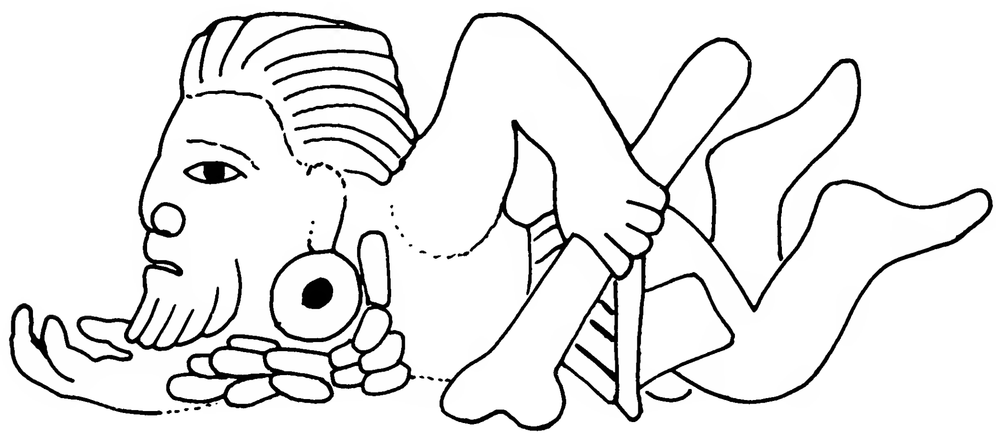

Fig. 4. Drawing of figure sculpted in relief on Tomb I at Lambityeco.

Just as important as the absence of supporting sculptural evidence, however, is the fact that at the Oaxacan type site of Monte Albán bowls were never mold-decorated and only painted, incised, modeled or sculptured.

The very shape of the small bowl is another reason to question an Oaxacan origin. It is not typical of Monte Albán. Its form is instead reminiscent of the mold-decorated bowls of Vera Cruz particularly those of the Rio Blanco region. We believe that if vessel B were found in Oaxaca, it got there by way of the active trade routes, probably during the early post-classic period.

The larger bowl A (Fig. 2) is readily identified as a Teotihuacán style tripod cylindrical pot with rounded stubby feet. Based purely on analysis of vessel shape it could conceivably have been produced in Oaxaca during Monte Albán III, which shows a broad diffusion of Teotihuacán influence. Such influence is, however, equally evident among the Maya and in Vera Cruz.

The characteristics of the two bowls' decoration give strong indication that they originate from Vera Cruz, and specifically from the influential classic Totonac ceremonial center of El Tajín, which had a reciprocal cultural relationship with Teotihuacán.

Looking first for the obvious clues, both bowls A and B exhibit the telltale "double line," so characteristic of El Tajín (fig. 5). It is prominent

in their elaborate interlacing architectural scrolls and is discernible as well on the outlines of the human form. On these examples, the "double line" is seen on the bent arm of the horizontal figure, the arm of the partially visible man on bowl A entwined with the monkey's tail, as well as on the monkey itself. This strongly suggests Tajín-Vera Cruz influence in our pieces.

Already having discussed "recumbent figures" in Oaxacan relief sculpture, we look for such human forms in Vera Cruz relief sculpture. The top decorative band of the South Central Panel of the South Ball Court at El Tajín, Vera Cruz (Fig. 5) presents a complex joining of two recumbent human figures to a common head which is in frontal view.

This panel is very helpful to our purposes. Both of the joined bodies are extended horizontally in similar fashion to the two bowls with arms bent to the waist. The hairlocks are in the same style and position. The ear plugs are similarly rendered, dropping directly before the slightly outcurving hair. The common face sports a small mustache and a triangular beard which would translate in profile into the Van Dyke of our man who also has a modest mustache.

Fig. 5. Drawing of a portion of a panel at El Tajín's South Ball Court.

In the center of the grouping of panel 3 of the South Ball Court at El Tajín are two erect male figures whose equipment mark them as ball players in the Mesoamerican ritual ball game, so intimately associated with human sacrifice to the gods. The contestant on the right, reproduced here (Fig. 6), points one hand at his opposite in conversation, as indicated by the speech scroll issuing from his mouth, and brandishes a flint sacrificial knife in the other. It is interesting to note his ceremonial belt (yoke) decoration – a round shield with three loops (feathers?) extending from it. It is identical to the somewhat magnified shield with loops at the waist of the bowls' horizontal figure, who, incidentally, also has a speech scroll curling from his mouth.

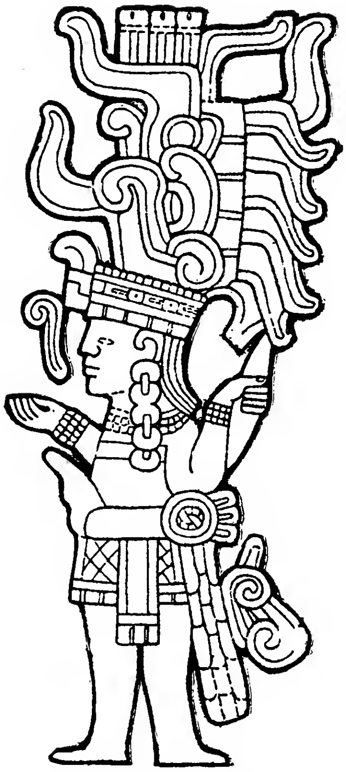

Fig. 6. Drawing of a player in the Mesoamerican ritual ball game.

The headdress of the main figure is elaborate and difficult to analyze because so much of it has been erased by the potter's spatula. It resembles an anthropomorphic mask, adorned with a rosette and flowing plumes, and with a billowing mustache, upturned at the ends. I have not seen any similar masks, but his unusual mustache is a prominent feature of that masterpiece of Mayan wood sculpture, the kneeling figure of the Museum of Primitive Art, New York (62.172).

What appears at first glance to be another speech scroll in front of the face of the mask does not have the free movement associated with that symbol. Speech scrolls generally curl down and inward at their ends; this element curls upward and back. Its straight shaft has some kind of binding, and furthermore, it sports three round tufts on the "curl." This strongly suggests the tip of a ceremonial scepter such as perhaps the serpentine *Xiuhatlatl* of the fire god (often snown as an attribute of *Quetzalcóatl*) and which in the Codex Borbonicus 23 is similarly adorned with round "tufts."

A delightfully rendered monkey leans over the awkward foot of the fallen ballplayer, while his tail engages the partially shown figure of another man. The man's arm is raised and what may be a ballplayer's belt (yoke) appears below. In contrast to the main figure, his face has a strong square jaw and slightly protruding lips. It resembles the head of a personage called 8 Conecuilli sculpted on a columnar disk recovered from the House of Columns at Tajín Chico, part of the site of El Tajín. Its headdress is similarly composed of a broad base band with vertical feathers rising from it.

Based on the foregoing considerations, it appears that the molds originate from Vera Cruz and possibly El Tajín itself. The thermoluminescent tests performed on the bowls permit their placement at A.D. 800-900, the time span in which the South Ball Court at El Tajín was constructed. The original Vera Cruz potter conceived his masterpiece and made his mold – trade could later have transported his mold, or finished vessels decorated from it, to other areas such as Campeche and Oaxaca, there to be discovered centuries later.

The tantalizing puzzle remains: what story is being told? Mesoamerican artists were not interested in realism *per se,* or art for art's sake, but in the conveying of an idea – generally by means of esoteric symbolism. We can only conjecture what may have been intended by the original and complete picture story. Surely the ritual ball game was involved, perhaps not for its own sake, but as a symbol of sacrifice, of an event to propitiate the demanding gods. But in what context, illustrating which myth, legend or tribal history? The presence of the monkey may be a clue. The Mexican creation myths tell of a succession of four Suns (worlds) each in turn destroyed. We are today in the fifth world, destined to destruction by earthquake. It was the second Sun, assigned to Wind, with the god *Quetzalcóatl* presiding, which was terminated by hurricanes. The surviving population was converted to monkeys by the unserved gods.

A slight variation from the Aztec cosmology is found in the *Popol Vuh*, the sacred book of the Quiché Maya of Guatemala. In it, one of the unsuccessful experiments by the gods was the creation of man from wood after clay had already proved disastrous. When the men made of wood proved themselves insufficiently responsive to the gods, they were transformed into monkeys to populate the forests. Also in the *Popol Vuh* is the beautiful saga of the hero-brothers Hunapuh and Ixbalanque. They punished their step-brothers Hunbatz and Hunchouen by driving them up a tree and converting them to monkeys. The heroes were successful hunters and ball players, whereas their brothers had wasted their time playing the flute and singing songs.

The monkey is very closely related to *Xochipilli*, the young god of pleasure, music and the dance. In the Codex Borgia 49, the monkey is the ballplayer of the east, symbolizing the gods of pleasure. As the animal of pleasure, in the typical allusion-movement pattern of Mesoamerican thought, he is as well the symbol of sinful desire, lust. In quite another context, possibly suggested by his sunken eyes, he also became identified with death; on many stone sculptures it is difficult to distinguish between a monkey head and a death head.

The monkey was introduced into the design in the preceding discussion for a purpose. Perhaps he speaks to us directly – if the "Second Sun" is our subject – or indirectly, serving to symbolize an applicable attitude or relationship to the theme. Someday, somewhere, perhaps the answer to this and our other conjectures will be forthcoming with the discovery of the complete design on the original and larger vessel.

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Drawings by Michael Sellon
Photographs by Carmela Guadagno

THERMOLUMINESCENCE DATING OF POTTERY

Victor J. Bortolot, Ph.D.
Radiation Research Dept.
Mount Sinai School of Medicine
New York City

On October 28, 1663, the English chemist, Robert Boyle, spoke before the Royal Society and described the phenomenon of thermoluminescence (TL) for the first time. He had studied a remarkable diamond which gave off a weak glow when placed on the warmest part of his body. It has since been discovered that other minerals exhibit this same phenomenon, in most cases after having received a heavy dose of ionizing radiation – alpha and beta particles, and gamma rays. What Boyle observed was the result of millions of years' exposure to radiation from the small quantities of uranium and thorium present in the diamond and its geological matrix. Many minerals, in fact, are thermoluminescent to some degree, but the majority require highly sensitive instruments to detect and measure the glow.

In crystalline materials, including minerals, the atoms are ideally arranged in a regular pattern, or lattice. Natural materials, however, have defects which interrupt this regularity. The defects may be impurity atoms, or atoms missing from the lattice, or crystal dislocations, all of these causing some distortion of the electric field holding the lattice together. These distortions give some of the defect sites a net positive charge, enabling them to attract and trap free electrons. Hence they are known as electron traps. When ionizing radiation travels through the crystal lattice, electrons are knocked free from some of the lattice atoms. These atoms, now positively charged, will attract the electrons back strongly. Most electrons will recombine immediately. A small fraction will, however, be trapped at defect sites.

When the crystal is subsequently heated, the lattice vibrates, and at some temperature depending on the binding strength of the traps, the electrons will be freed and will recombine with lattice atoms. In the process, each electron emits a photon – light measurable in a laboratory.

The experimental apparatus for measuring TL is straightforward, and is shown schematically in Figure 1. The TL sample is placed on an electrical resistance heater and raised in temperature at a constant rate, usually 20°C/second, up to about 500°C. The sample is viewed by a sensitive photomultiplier tube light detector, and the intensity of the light given off is plotted against temperature to produce what is called a "glow curve."

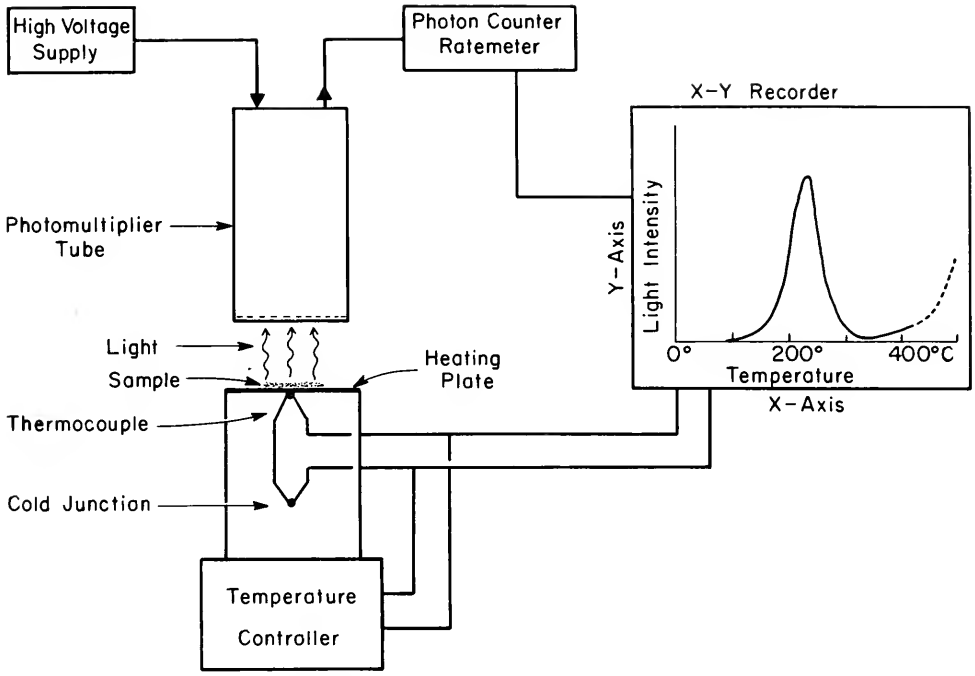


Figure 1. TL measurement apparatus. A sample of lithium fluoride which has been exposed to cobalt-60 gamma rays is placed on a nichrome plate and heated electrically at a rate of 20°C/second. Light emitted by the sample is detected by the photomultiplier tube and plotted on the *y* axis of an *x-y* recorder against temperature on the *x* axis. The height of the peak is proportional to the dose of radiation. When the sample is heated a second time, only the thermal background, the incandescence or "red hot glow" of the sample, is recorded, appearing above 400°C.

Above 400°C, the incandescence, or "red hot glow," of the sample is detected. The incandescence is distinct from the radiation-induced TL and must be subtracted. When the sample is run up in temperature a second time, only the incandescence is found.

The number of traps filled with electrons, hence also the light detected, is proportional to the radiation dose absorbed by the thermoluminescent material, so that an unknown dose can be determined by comparison with the TL produced by a known, calibration dose. This useful property is the basis of thermoluminescence dosimetry which has become an important tool in a number of fields, most notably in medicine, radiation safety, geology, and most recently, archaeology (Auxier *et al* 1968; Aitken and Fleming 1972:1-78). After World War II, when atomic energy research started in earnest, some means of monitoring the exposure of personnel to dangerous radiation became necessary. One of the methods investigated was TL dosimetry. By 1952, Farrington Daniels of the University of Wisconsin, "the father of TL dosimetry," had examined several thousand minerals, looking for a good dosimetry material, and found that more than half were thermoluminescent, including many found in pottery clays (Daniels *et al* 1953:343).

Daniels hinted then that pottery could be dated by its TL if the rate of dose accumulation were known, but the idea remained untested until 1960 when Kennedy and Knopff made an early trial (Kennedy and Knopff

1960:147). A number of laboratories around the world began work on the technique, and despite early difficulties, it has now become a useful tool, though hardly at this time comparable in accuracy to radiocarbon dating. The most notable success has been achieved by Martin Aitken and his colleagues Michael Tite, David Zimmerman, and Stuart Fleming at the Research Laboratory for Archaeology, Oxford University. Other laboratories active in the field are at the Danish Atomic Energy Establishment, Risö (Mejdahl 1969:99), the University of Pennsylvania (Ralph and Han 1966:347), and the University of Birmingham, England (Fremlin 1968). More recently established are laboratories at Washington University, St. Louis (Walker and Zimmerman 1974:19) and at Mt. Sinai School of Medicine, New York (Bortolot *et al* 1973:847).

Pottery is made by firing clay in a kiln to a temperature of 600-1000^{o}C. This empties the electron traps of electrons that had accumulated since the clay minerals had formed, in effect setting the TL "clock" to zero. When the pottery cools, ionizing radiation will again fill traps, so that the accumulated radiation dose, as deduced from the pottery TL, will be proportional to the time since the clay was fired. Thus when the dose per year absorbed by the pottery is determined, the age may be found absolutely from the simple expression:

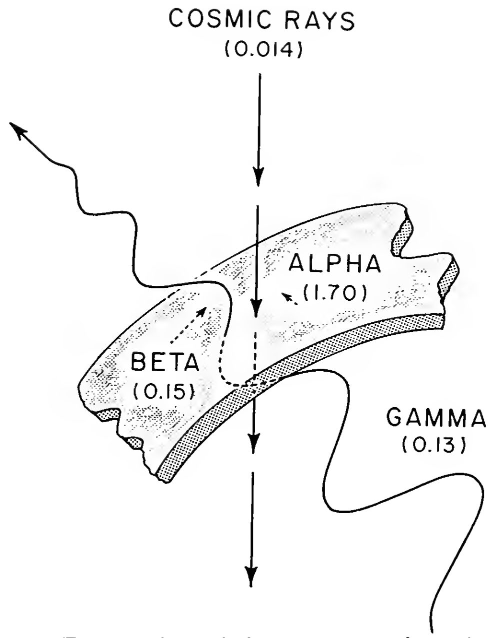
$$\text{Age (years)} = \frac{\text{Accumulated Dose (rads)}}{\text{Dose Rate (rads/year)}}$$

The rad is the unit of radiation dose (100 ergs/gram energy absorption), and one is the equivalent of about four chest x-rays.

The typical radiation environment of a potsherd (Figure 2) results from parts per million concentrations of uranium and thorium, and percent concentration of potassium. The relatively scarce potassium-40 (0.012 per cent of all potassium) is radioactive and decays to argon (the basis of potassium-argon geological dating). Uranium-238 and thorium-232 are at the head of long alpha decay series which end in the stable isotopes lead-206 and-208, respectively. The range of alpha and beta particles is quite short, while gamma and cosmic rays are strongly penetrating. Consequently, the potsherd will experience only the gamma and cosmic ray component of the external radiation except in a thin surface layer. By the same token, the alphas and betas originating within the sherd will be completely absorbed there and contribute to the TL, but the gammas will escape to be absorbed in the surrounding soil.

The amount of the uranium and thorium series present in the pottery is determined by alpha scintillation counting. When an alpha particle strikes a zinc sulfide phosphor screen, there is a flash of light which is detected by

Figure 2. Typical annual radiation dose (in rads) of a pot sherd buried in soil. Both pottery and soil have uranium 3 parts per million, thorium 12 parts per million, and K_2O one per cent. The ranges of the different components of radiation are indicated by the length of arrows: alpha particles (20-50μ), beta particles (1-3 mm), gamma rays (tens of centimeters), and cosmic rays (meters). The total dose is close to 2 rads, but as the TL efficiency of alpha particles is typically about 20 percent that of betas and gammas, the *effective* dose is 0.63 rad (54 percent alpha, 24 percent beta, and 22 percent gamma).



a photomultiplier tube and counted. From the alpha count, the alpha, beta, and gamma dose rates are computed, making some assumptions about the relative amounts of uranium and thorium and the equilibrium of their decay series (Table I). The potassium content is measured by flame photometry. The external gamma dose rate may be determined by analyzing the burial soil as above, or more directly, by reading out sensitive TL dosimeters left buried at the site for some months (Aitkin 1968:281). There is a basic assumption made here that the dose rates have remained constant since the pottery was buried. The accuracy obtained for TL dates appears to confirm this.

TABLE I

DOSE RATE MEASUREMENTS[a]

SOURCE	DOSE RATE (RADS/YEAR)		
	α	β	γ
Thorium-232 series[b]	1.27	0.042	0.119
Uranium-238 series[b]	1.36	0.062	0.059
U/Th = 0.5	1.32	0.054	0.083
1 percent K_2O	—	0.071	0.022

a. After Zimmerman 1971.
b. 10 alpha counts / 1000 seconds, 85 per cent counting efficiency, 44 mm diameter thick sample.

Determination of the dose rate presents the most difficulty in TL dating and is the major source of error. Many corrections must be made, including, for example, those for water content (water absorbs radiation)

and radon loss. Radon is a radioactive gas occurring half way down the uranium decay chain; any loss will upset the series equilibrium and result in dose rate computation errors.

We now come to the first of the many complications that beset TL dating. In the early days of TL dating, the dates found were much too recent, typically one-third the known age. It then was discovered that the alpha particles which contribute the largest part of the dose have a much smaller efficiency to produce TL than beta or gamma radiation – only 5 to 40 percent as much. So the pottery TL sensitivity must be calibrated with an alpha dose as well as with a beta or gamma dose (betas and gammas yield equal TL in pottery). The measured alpha dose rate is then multiplied by the TL efficiency ratio $k = (TL/rad)_{\alpha} / (TL/rad)_{\beta\gamma}$ to give the *effective* alpha dose rate. In the example of Figure 2, the effective total dose rate is reduced from nearly 2 rads/year to about 0.6 rad/year.

A further problem is that pottery is not homogeneous. It is a mixture of fine clay and sand grit, some added by the potter as "temper" to improve the working properties of the clay. Now, as it happens, most of the radioactivity is found in the fine opaque clay grains, while most of the TL comes from the sandy inclusions, mostly quartz and feldspars. The alpha particles can travel only 20-50μ (0.001-0.002 inch), but many of the mineral inclusions are far larger. The alpha dose in the interior of larger grains will be greatly diminished, so that the accumulated dose there will be about half that in the fine grains. If the whole sherd is ground up, the TL date resulting will be too recent. The solution is to separate different grain size fractions. The fine ones, 10μ diameter or less, have the full alpha dose, while the large grains, 100μ and more, can be etched with hydrofluoric acid to remove the outer layer and thus will have no alpha dose. Both fractions have the same beta and gamma doses, however.

These two approaches have been refined at Oxford (Zimmerman 1971:29; Fleming 1970:133) and yield comparable accuracy – an average TL date for about five sherds from an archaeological context will differ from the historical or radiocarbon date for that context by 7-10 percent, with a spread of 10-15 percent among the individual dates.

A third approach, under investigation now at Washington University, makes use of highly radioactive zircon crystals which are often found among the sandy inclusions (Zimmerman *et al* 1974:19). These contain such a large concentration of uranium (up to one percent) that all other sources of radiation may be neglected. The sand core of the controversial Greek bronze horse at the Metropolitan Museum of Art was authenticated by this means since it had been extensively x-rayed. The small size (about 125μ diameter) and relative scarcity of the zircons, each of which must be

analyzed separately, make this technique extremely difficult at present.

The method employed in this author's laboratory is based on the Oxford fine grain technique (Zimmerman 1971:29), chosen for simplicity of sample preparation and relative insensitivity to uncertainties in environmental dose rate (which often cannot be measured when the pottery, especially art objects in museums and other collections, has been carefully cleaned). A sherd fragment weighing about 1 gram is crushed gently in a vise after about a millimeter of surface is removed. This tends to break grains along their boundaries, rather than fracture them, and few large inclusions are broken into particles smaller than 10μ. The crushed pottery is shaken in acetone and allowed to settle for a short time, after which the solvent with fine particles in suspension is poured off onto a number (usually ten) of 1 cm aluminum disks and evaporated. The residue is retained for alpha counting and potassium analysis. Typical sample weight per disk is about 1 mg, and reproducibility of TL among the disks is quite good. When only a small sample can be spared, in the case of art objects for example, a small hole can be drilled in an inconspicuous spot to yield a total sample weighing 25-100 mg. The disks are prepared as before. The drilling unfortunately does break up inclusions and some assumption about the effective alpha dose rate must then be made. A satisfactory rule of thumb solution is halving the TL efficiency ratio (Fleming *et al* 1970:157). This will, of course, increase the date error, but often in these cases the only question is whether the piece is old or recent and such errors are unimportant.

The next step is determination of the natural TL and the alpha and beta TL sensitivities. Four disks are read out to obtain the natural glow curve. Two others are given a beta dose sufficient to produce a natural plus calibration glow curve about double the natural. Another two are given double the first beta dose to determine whether the TL is proportional to dose. If not, considerable error can result and such a sherd should be excluded from a dating program. The last two disks are given an alpha dose about five times the first beta dose. After the thermally stable portion of the glow curve is found (see Figure 4), the TL due to the calibration doses is found by subtracting the natural TL in the chosen temperature region. The sensitivities $(TL/rad)_\alpha$, $(TL/rad)_{\beta\gamma}$ and their ratio k are found, and the effective dose D_β = natural $TL/(TL/rad)_{\beta\gamma}$ computed.

The four disks read out for the natural TL are then each given a beta dose from one quarter to twice the dose D_β, and a TL/dose curve plotted. Occasionally some non-linearity is found at low doses, above which the curve becomes linear, and an intercept correction, I, may be required.

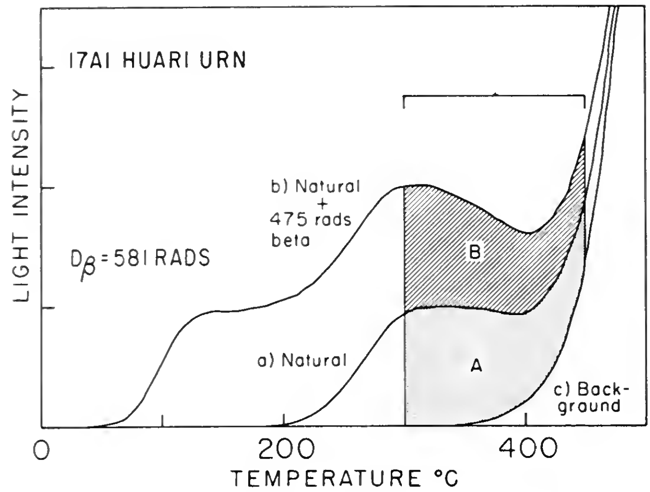


Figure 3. Thermoluminescent glow curve of the Huari urn. The intensity of light emitted by the sample is plotted against temperature. Curve *a* is the natural TL of the pottery, *b* is that due to the natural accumulated dose plus an additional 475 rads Sr^{90} beta dose, and *c* is the thermal background. Thus area A corresponds to the natural dose while B corresponds to the calibration dose alone. The ratio of the two areas determines the natural dose in the pottery, in this case 581 rads. The effective dose rate is 0.460-0.616 rad/year and the age of the piece is thus 940-1260 years.

Since the low-temperature part of the TL glow curve is subject to decay at normal environmental temperatures, its shape will be markedly different for a calibration dose with immediate readout and for a natural dose accumulated over many centuries. It is necessary therefore to choose for analysis only the portion of the glow curve that is thermally stable for long periods of time. This temperature region is conveniently found by taking the ratio of the natural glow curve to the natural plus calibration glow curve. At some temperature the ratio will reach a plateau, indicating that the two curves have the same shape. The region above this point is thermally stable.

We now have all the elements necessary to compute the age of the pottery: the effective dose, the intercept correction (if any), the relative alpha TL efficiency, and the computed internal and external dose rates. Considering that a half dozen or more parameters must be measured or calculated to give a TL date, the accuracy obtained is quite respectable. Unfortunately, it is not likely to approach that of radiocarbon dating for some time, if at all.

To date, the major effort in TL dating research has gone for establishing the validity of the technique and for authenticity studies, which are relatively easy. Recently, though, there have been some archaeologically interesting results, particularly from Oxford. TL is particularly useful, as one might expect, when no organic material for radiocarbon dating survives at a site, but it is also helpful as a back-up technique when the radiocarbon dates may be suspect on the grounds of possible sample contamination or some other reason.

As an example, fired clay fragments associated with pottery figurines excavated at Dolni Vestonice, Czechoslovakia were studied by Zimmerman and Huxtable (Zimmerman and Huxtable 1971:53). The radiocarbon age for that context is 28,300 years (5730 year half-life), making these objects

the oldest known pottery. The TL date found was 33,000 $\pm$ 3000 years, fairly consistent with the radiocarbon date. The 4700 year difference follows the trend of the bristlecone pine corrections, and represents the first step toward correcting radiocarbon dates in a period for which neither tree-ring nor varve measurements are available. This study further showed that the glow curve above 350°C is stable for very long periods of time.

Recently, a group of aboriginal hearths found at Lake Mungo in Australia showed by thermoremanent magnetism* that a brief near-reversal of the earth's magnetic field occurred between 31,000 and 26,000 B.C. (radiocarbon dates). There was a worry that the change in magnetic field could have caused a temporary increase in carbon-14 production which would make any organic material living at that time appear to be too recent. Burnt clay pot boilers were found with the hearths and dated by Huxtable (Huxtable 1973). The TL dates were about 5000 years older than the radiocarbon dates with errors of 3000-4000 years. No significant discrepancy in age was found for the hearth in use when the magnetic field was reversed, indicating that the effect was much smaller than was feared.

By far the most useful application of TL dating has been in authenticity testing. With the soaring prices for antiquities today, a great quantity of forgeries and deceptive reproductions have come onto the market and been sold as genuine. Some are shoddy imitations and are readily dismissed as such, but others, particularly when original molds have been used, are extremely difficult or impossible to detect by the customary standards of style, iconography, and technique. With TL it is usually a simple matter to determine at least whether a piece is old or not, and with more effort the dating can be made sufficiently precise to be of some assistance to the art historian.

A few examples will serve to show that TL authenticity surveys can lead to surprising results, often disturbing, which indicate the power of the technique. A number of years ago the late neolithic site of Hacilar in southwest Turkey was discovered, and the excavations yielded distinctive types of anthropomorphic vessels and figurines. Many of these soon found their way onto the antiquities market. By 1969, some doubts about the authenticity of certain of these objects arose, and Aitken at Oxford undertook to clarify the situation by TL analysis (Aitken *et al* 1971:89). Of sixty-six items tested, only eighteen were found consistent with a sixth millenium date. An even more appalling example is found in the case of a

*Many rocks and clays contain magnetic iron oxides. These, when heated above a certain temperature called the *curie point*, lose whatever permanent magnetism they may have had, and acquire a new magnetism. This is in the direction of and proportional in strength to whatever magnetic field (usually the earth's) surrounds them. On cooling, this new magnetization is "frozen" in. If the position of the rocks or fired clay has not been altered, it is possible to obtain information about the earth's magnetic field at the time of heating.

distinctive group of pottery objects said to have been excavated near Hui Hsien in Honan province, China, which began to appear on the antiquities market in the early 1940's. These objects subsequently attracted a great deal of attention and commanded high prices. Soon "genuine" and "fake" Hui Hsien figurines were being distinguished on stylistic grounds. A cloud of uncertainty as to the authenticity and provenance of the group as a whole arose in the early 1950s and work on it ceased. Recently, the case was reopened when twenty-two of the objects were studied at Oxford by Fleming and Sampson (Fleming and Sampson 1972:237). All proved conclusively to be of modern origin. On the other hand, a survey of 117 Oaxocan funerary urns from the St. Louis Art Museum by Zimmerman at Washington University showed that only seven were of recent manufacture, against the thirty to thirty-five predicted on the basis of style (Zimmerman and Shaplin 1974). Only two of the modern pieces detected were among the group thought to be so. The major reason for this apparent breakdown in stylistic analysis is probably the poor reputation these pieces have acquired because of the many forgeries detected in the past. This class of objects has largely been ignored and mistrusted by the art historian. TL can thus provide the valuable service of establishing a corpus of known genuine pieces on which the art historian can work with confidence.

It is pertinent at this point to discuss very briefly the possibility of gross error, that authentic TL behavior could be simulated by a modern faker or that an authentic piece recently refired for some purpose could be judged a forgery. Simple irradiation of modern pottery by x-rays or gamma rays, even if the appropriate dose were known, cannot reproduce authentic TL response for two reasons: first, which would be a tip-off, the glow curve shape would be wrong, having too much low temperature TL if the dose were given just a few years prior to testing. Much more fundamental is the difference in dose between the fine and larger grains, as mentioned above. One expects a 20-50 percent smaller dose in the large grains which have no alpha dose contribution. If the same were found, one would have a good case for imputing fraud. Even if a clever forger were able to get by this test (and he would have to be extemely clever and resourceful, and be skilled as well in TL and radiochemistry), there is a further hurdle which would be impossible to surpass. That is the very high dose of the radioactive zircon inclusions, which is around a hundred times greater than the remainder of the pottery. Admittedly, one would have to have strong suspicions to carry an analysis this far, but a sure test exists should it be needed.

The other source of trouble, modern refiring, is undetectable by TL if the temperature were sufficiently high, and one must look for other physical signs of its occurrence. If the heating is less extreme, however, as for example in drying out wet finds, a sensitive test exists that was devised by Fleming. A low temperature TL peak of quartz having a TL sensitivity strongly dependent on thermal history, can indicate the maximum temperature of reheating (Fleming 1971:159). Claims that such treatment of the Hacilar material invalidated the TL results were refuted in this manner.

In sum, the possibility of deceiving TL analysis is slight. A greater danger lies in a bad choice of sample sites. Obviously TL dating concerns only the sample actually analyzed. Any modern restoration in a genuine piece will show up as modern, just as a pastiche made of unrelated bits of old pottery will be judged genuine. In the latter case, the age and radioactivity may differ for different parts of an object. When any restoration is suspected it is generally wise to take two or more samples.

We will conclude with a number of examples of dating: three objects from the collection of the Museum of the American Indian and two from private collections.

HUARI TIAHUANACO URN (16/9700)

This impressive work of Peruvian art (lab. ref. 17A1, pages 4 and 5), described elsewhere in this journal by Anna Roosevelt, was thought suspicious on the basis of a peculiar iconography and removed from exhibition fifteen years ago. A recent technical examination by Robert Sonin showed nothing inconsistent with genuine material, which would be unusual for a forgery made prior to 1930 when the piece was acquired. It was brought to the author for confirmation of its authenticity by TL. A sample of about 100 mg was drilled out of a piece of the rim which had broken along an old repair. The glow curve is shown in Figure 4. The equivalent dose is 581 rads, with no intercept correction, and the relative alpha efficiency is 0.26, but is assumed to be half that, 0.13, to allow for large grains broken up by the drill. The dose rate measurements are given in Table 2. It is unfortunately impossible to measure the environmental dose rate, a range of 0.014 rad/year (cosmic rays alone) to 0.170 rad/year provide reasonable limits. If the urn were buried in the material it is made of, the environmental dose rate would be 0.168 rad/year; much less if buried, say, in sand. Taking the range first mentioned, the total effective dose rate is 0.420 to 0.616 rad/year, giving an age 940 to 1260 years B.P., or 710 to 1030 A.D., quite consistent with the urn's attribution to the Huari period. The actual error margin should be somewhat greater, due to the assumption about k, but it is difficult to estimate.

Figure 4. Early post-classic Veracruz jar, height 7.8 cm. MAI/HF 23/9540 (Lab. ref. 17A2).

Figure 5. Early post-classic Veracruz jar, height 15.5 cm, companion piece to that shown in Figure 4. MAI/HF 24/784 (Lab. ref. 17A3.2).

TWO EARLY POST-CLASSIC VERACRUZ JARS

These two jars (Figures 5 and 6), made from slabs formed in the same mold, were acquired separately, and given different provenances. Curt Muser, in this journal, attributes both to early post-classic Veracruz. To the eye, the pottery fabrics of the two appear identical, and the TL and radioactivity measurements lend additional evidence to their being made in the same locale. The smaller jar (23/9540, lab. ref. 17A2) was sampled from the bottom, while the larger (24/784, lab. ref. 17A3.2) was sampled from a flat part on the surrounding design, since the bottom was restored; the three legs are actually plaster. The glow curves are very similar and only that of 23/9540 is shown (Figure 7). All measurements are given in Table 2. The range of dates for 23/9540 is 850-1340 B.P. or 1020 B.P. if the environmental radiation matched that of the pottery. For 24/784, the equivalent ages are 890-1370 B.P. and 1050 B.P. Note that in the second case an intercept correction of 60 rads was included. The dates fit in well with the period assigned. The dose rates are computed for dry pottery; if buried at a wet site, as is likely, the ages could be up to 10 percent greater.

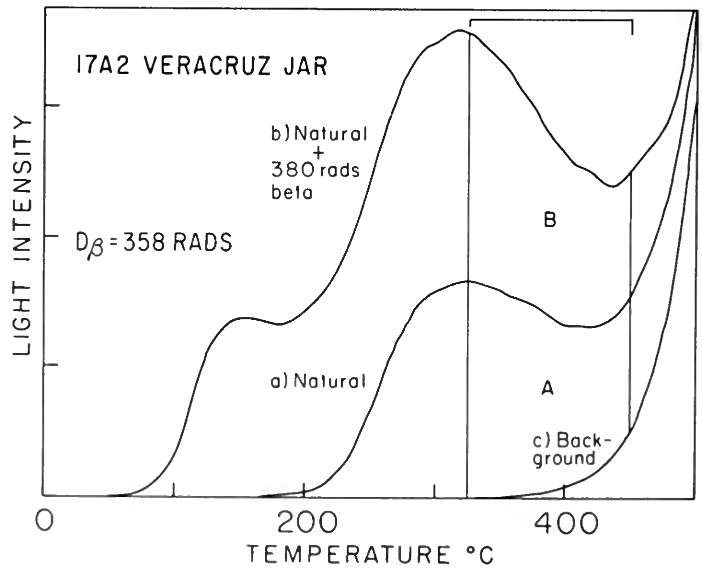


Figure 6. TL Glow curve of 17A2.

Figure 7. Small Monte Albán-type votive incense burner(Lab.ref. 3A1) considered to be a forgery, but dating from *circa* 900 A.D. if genuine, Height 12 cm.

Private collection.

Photograph by Robert Hein

MONTE ALBÁN INCENSARIO

The mold-made votive incense burner (lab. ref. 3A1) shown in Figure 8 is in a decadent Monte Albán style (*circa* 900 A.D.) and was considered probably to be fraudulent on stylistic grounds. The manner of firing was suggestive, however, that the piece might in fact be genuine, but of poor quality. The glow curve shown in Figure 9 indicates that the total accumulated dose is only 3.8 rads. At the very least the dose rate is 0.014 rad/year from cosmic rays, so the maximum age is just 270 years. The piece has been recently fired, and may be considered a fake. In such clear-cut cases as this, no radioactivity measurements are necessary. Since the typical effective dose rate is about 0.5 rad/year, the actual age of the piece is about 8 years.

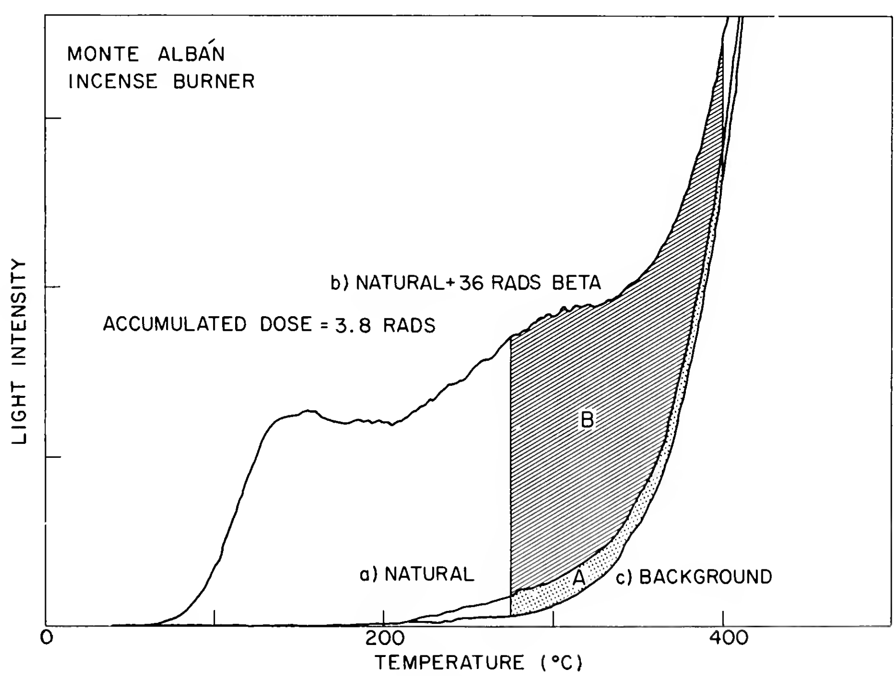


Figure 8. TL Glow curve of 3A1. The equivalent dose here is only 3.8 rads. Even if the sole source of radiation had been cosmic rays, the figure could be no older than 270 years. Since the effective dose rate to pottery is roughly 0.5 rad/year, the actual age is about 8 years. The object has definitely been recently fired.

Figure 9. Cast gold bird finial, Sinú, Colombia (Lab. ref. 20A1). Height 9.2 cm. The figure contains a clay and charcoal core, heated during casting, which can be TL dated. Collection of John Stokes

Photograph by Robert Stokes

SINU BIRD FINIAL

Pottery is not the only material datable by TL. Any mineral material which was heated strongly at the time we wish to date from can be used, for example stones used as pot boilers, burnt flints, or in this case, the investment core from a lost wax gold casting. The bird finial from Sinú, Colombia (lab. ref. 20A1.2, Figure 10) is quite early, *circa* 500-1000 A.D. It has a gritty clay and charcoal core around which the wax model was formed. After the model is packed in investment, the wax is burnt out and the molten metal poured in. The heat is sufficient to drain the TL from the core, so that dating is possible. Here, the inclusion method was used with material of -200, +300 mesh. The glow curve is given in Figure 11, and the measurement data presented in Table 2. Burial soil was found still

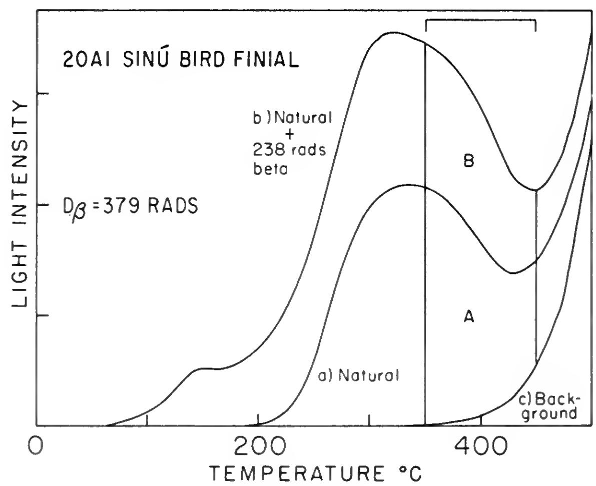


Figure 10. TL glow curve of 20A1.

adhering to the interior of the object and was analyzed to give the environmental dose. The k value for the case is low, consistent with quartz, and must be reduced to about one third, or 0.012, to allow for alpha attenuation since there was no etching to remove the outer layer. The gamma dose is probably not attenuated too much by the thin gold wall and no correction is made. The total effective dose rate is 0.207 rads/year, giving an age of 1830 years.

We have seen that thermoluminescence dating, while conceptually simple, does possess complexities which render accurate dating difficult. The accuracy is not yet sufficient for TL to challenge radiocarbon, but it is

an important back-up when radiocarbon is impossible or untrustworthy. While few dates of interest to the archaeologist have yet been published, the potential of this new technique is great. The simple authentication of material has already been of benefit to the art historian. This method of absolute dating should in the near future become a standard tool for both the art historian and the archaeologist.

This work was supported in part by the Hoffman Radiation Research Fund, New York, N.Y.

TABLE 2

TL AND DOSE RATE MEASUREMENTS

SAMPLE	DOSE (RADS) $D\beta$	I	k	α COUNTS/ 1000 SEC	K_2O %	EFF. DOSE RATE (DRY) (RAD/YEAR)				AGE (YEARS B.P.)
						α	β	γ	TOTAL	
17A1 (16/9700)	581	0	0.13[a]	12.3	2.4	0.211	0.235	0.014– 0.170 0.168[b]	0.460-0.616	940-1260
17A2 (23/9540)	358	0	0.13[a]	4.3	2.2	0.074	0.179	0.014– 0.170 0.098[b]	0.267-0.423	850-1340
17A3.2 (24/784)	341	60	0.15[a]	4.0	2.5	0.079	0.200	0.014– 0.170 0.102[b]	0.293 0.449	890-1370
3A1	3.8	–	–	–	–	–	–	> 0.014	> 0.014	< 270
20A1.2	379	0	0.035	6.5	0.9	0.010	0.099	0.098[c]	0.207	1830

a. One-half the value measured, in compensation for presence of broken up inclusions.
b. Computed for soil of same composition as pottery.
c. From soil analysis.

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